Emissivity measurements of 3D photonic crystal

T.S. Luk, I. El-Kady, J.G. Fleming, R.A. Ellis, J.C. Verley, W.W. Chow
Sandia National Laboratories, P.O. Box 5800,
Albuquerque, NM 87185

The ability of a photonic crystal to mold and control light forcing thermal energy to emit in a relatively narrow spectral band has intrigued scientists and engineers in optics and physics. In particular, there is interest in driving photonic crystal emitters out of equilibrium. In this way, the spectral brightness of the emission will no longer be limited by Planck's law.

Indeed, a quantum optical model of an ensemble of two level emitters suggested that a nonequilibrium condition can be achieved even when the heat source is thermal in nature. This is due to the fact that the temperature of the emitters is not necessarily the same as the photonic crystal itself. This result has tremendous implications for thermophotovoltaics, efficient lightning and IR scene generator applications. However, experimentally it is difficult to determine the temperature of the photonic crystal or the emitter ensemble. Hence, the equilibrium state of the emitter ensemble is unkown. To circumvent the difficulty of performing accurate temperature measurement without disturbing the system, emissivity measurements are employed. Using the fact that emitters in thermal equilibrium cannot have an emissivity greater than 1, absolute emissivity measurement is the most direct way to determine whether emitter population is in thermal equilibrium. The challenges to achieve accurate emissivity measurements include insuring the reference and samples are in isothermal condition and the emissivity of the reference sample is well characterized, especially at temperatures exceeding 1000K. In this paper we will report absolute emissivity measurements on a 3D tungsten woodpile photonic crystal. These results are used to validate theoretical emission models based on Langevin and quantum optics approaches. Furthermore, the effect of relaxation dynamics on the emissivity will be discussed. Experimental data on emission anisotropy and polarization dependence will also be presented.

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